EEDP-01-27
November 1992

# Environmental Effects of Dredging Technical Notes



## A Computer-Assisted Expert System for Interpreting the Consequences Of Bioaccumulation In Aquatic Animals (*COBIAA*)

### Purpose

This technical note describes a prototype expert system being developed to assist managers and scientists in the interpretation of bioaccumulation test results and their potential effect on the disposal of dredged material. This is a microcomputer (MS-DOS™) based system, operating in the Microsoft Windows™ environment.

### Background

Two types of sediment bioassays may be conducted in the regulatory evaluation of dredged material: toxicity tests and bioaccumulation tests. *COBIAA* (for *C*onsequences *O*f *B*ioaccumulation *I*n *A*quatic *A*nimals) is an expert system being developed to help interpret results of bioaccumulation tests, which incorporates toxicity data in the final decision. Because regulatory decisions are based on both types of bioassays, this note includes a brief overview of the two types.

### Additional Information

For additional information, contact the authors, Mr. Charles H. Lutz, (601) 634-2489; Mr. Eric Markstrom, (317) 494-8041; Dr. Thomas Dillon, (601) 634-3922; Dr. Jeff R. Wright, (317) 494-8041; Dr. Mark H. Houck, (703) 993-1737; or the manager of the Environmental Effects of Dredging Programs, Dr. Robert M. Engler, (601) 634-3624.



US Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

## Interpreting Toxicity Tests

Sediment bioassays designed to evaluate the toxicity of dredged material are called toxicity tests. Typically, survival or some biologically important sublethal endpoint, such as growth or reproduction, are measured in appropriate test species following laboratory exposure. All sediment toxicity tests are conducted to meet two objectives: evaluate material with high precision and accuracy and predict potential biological impacts in the field.

Most research and development has focused on the first objective. Little effort has been devoted to field verifying sediment bioassays. Currently, sediment bioassays cannot be considered precise predictors of biological impacts in the field. Testing the requisite number of animals from a variety of trophic levels under simulated realistic field conditions is too time- and resource-intensive, especially for a regulatory program. Rather, the approach adopted jointly by the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency (EPA) is to evaluate worst-case scenarios using appropriate test species. Animals are spatially confined under rigorously defined exposure conditions to the project sediment for a period of days to weeks. Survival, growth, and/or reproduction are measured and compared to a reference sediment treatment. Results are analyzed statistically and an evaluation is made regarding the *potential* for unacceptable adverse impact due to the project dredged material. Statistical significance cannot be used to *predict the occurrence* of field impacts. Rather, the results of sediment toxicity tests are used to *project the possibility* and the relative magnitude of potential impacts.

## Reference Sediment Approach

The second way to facilitate projections of potential field impacts from sediment bioassays is to make *relative* rather than *absolute* comparisons. This is accomplished by using a *reference* sediment. The reference sediment is selected to simulate, as closely as possible, the disposal site environs in the absence of dredged material disposal. In laboratory experiments, the biological response in the project dredged material is compared to that in reference sediment. If results are indistinguishable, one infers that the potential for unacceptable adverse impacts is low to nonexistent.

## Interpreting Bioaccumulation Tests

Bioaccumulation tests are conducted to demonstrate whether environmental contaminants have the potential for moving from the sediment matrix into aquatic animals. As with toxicity tests, *relative* comparisons are carried out using a reference sediment. If there are no significant differences in bioaccumulation between project and reference sediments, one concludes that the potential for bioaccumulation does not exist. If, however, significant bioaccumulation is observed, one must interpret the importance of the resultant tissue residues. To date, this interpretation has varied widely and lacked a sound technical framework. The *COBIAA* computer-assisted expert system will help provide this framework.

Interpreting bioaccumulation data is generally more difficult than interpreting results of sediment toxicity bioassays, involving a weighing and balancing of many factors, some intuitive and some quantitative. All these evaluations are carried out in the context of two categories of potential target receptors: aquatic organisms and humans.

## Need for an Expert System

Very few people have the knowledge and expertise to interpret bioaccumulation and toxicity data to reach a conclusion concerning the appropriate disposal of dredged material. This interpretation of the data is approached by different people in varying ways, creating a lack of consistency. *COBIAA* is based upon the procedure followed by an expert in this field to assess this type of data. Using *COBIAA* will allow managers and scientists to follow the same determination process in spite of not having the necessary experimental background needed to make these kinds of decisions. To provide flexibility, *COBIAA* will permit defaults to be modified, but will require the user to input a justification for these changes. *COBIAA* does not attempt to provide the definitive answer to the question of whether a particular sediment should be dredged or whether the sediment is acceptable for ocean disposal, but adds to the knowledge base needed to make this decision.

Figure 1 shows the underlying structure of the decision process used by *COBIAA*. Each step of the hierarchy represents the attributes or categories that *COBIAA* uses to reach a decision. None of the basic attributes (T1, T2, B1, B2, B3, B4, and B5) is more or less important than the others in the decision process. The



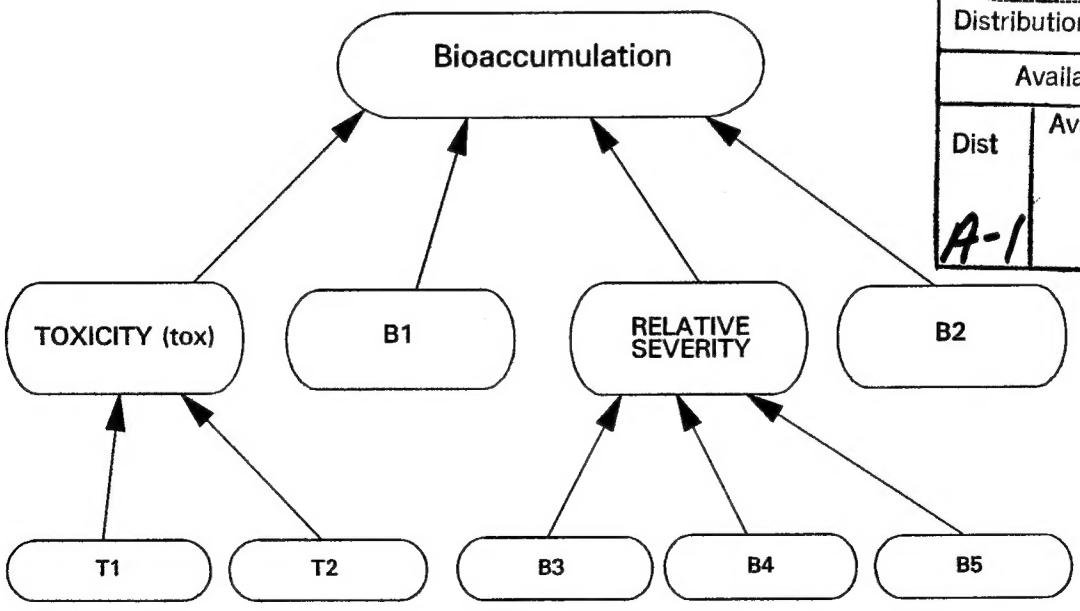


**Figure 1. *COBIAA* attribute hierarchy**

other two attributes, toxicity and relative severity, are used as intermediate steps in the decision process to pool the data from several basic attributes. This pooling of data from several attributes allows them to change the impact each individual attribute has on the decision.

*COBIAA* is most properly viewed as a decision support system (DSS), with an expert system component, for solving an ill-defined management problem as described previously. As a DSS, *COBIAA* is made up of three components: a compilation of rules and attributes, a set of data, and a user interface.

## Overview of the Attribute Hierarchy

The basic attributes are divided into two types, those based on toxicity data and those based on bioaccumulation data. *COBIAA* is designed to interpret bioaccumulation data, but in so doing uses the toxicity data to assist in this interpretation.

- Attribute T1 — number of different species showing toxicity when exposed to the same test sediment. This attribute attempts to take into account the sensitivity levels of various species to contaminants. Possible values of the T1 attribute are:

| Range of Values | Level of Concern |
|---|---|
| 0 | Low |
| 1 | Medium |
| > 1 | High |

- Attribute T2 — magnitude of toxicity above reference caused by the same test sediment used in attribute T1. If the toxicity levels of the test sediment are only slightly above reference, there is less cause for concern than if they are twice the reference. Possible values of the T2 attribute are:

| Range of Values | Level of Concern |
|---|---|
| 0 percent | Low |
| 1-20 percent | Medium |
| > 20 percent | High |

- Attribute B1 — number of phylogenetic groups showing statistically significant bioaccumulation relative to reference levels. This attribute attempts to account for varying levels of sensitivity to bioaccumulation in different taxa of animals. Possible values of the B1 attribute are:

| Range of Values | Level of Concern |
|---|---|
| < 2 | Low |
| 2 | Medium |
| > 2 | High |

- Attribute B2 — proportion of contaminants of concern bioaccumulated to concentrations statistically exceeding reference levels. This attribute attempts to determine the severity of the bioaccumulation problem. Possible values of the B2 attribute are:

| Range of Values | Level of Concern |
|---|---|
| < 10 percent | Low |
| 10-50 percent | Medium |
| > 50 percent | High |

- Attribute B3 — magnitude of test sediment bioaccumulation above reference levels. This is a different measure of the severity of contaminant bioaccumulation. Possible values of the B3 attribute are:

| Range of Values | Level of Concern |
|---|---|
| 0-20 percent | Low |
| 21-100 percent | Medium |
| > 100 percent | High |

- Attribute B4 — toxicological importance of contaminants bioaccumulated from the test sediment to concentrations exceeding reference levels. The contaminant rankings are based on EPA Water Quality Criteria (Lee and others 1991), which indicates that certain contaminants are of more concern if bioaccumulated than others. Contaminants not listed in the EPA table are not assigned an attribute value and therefore not used by *COBIAA* in the decision process for those contaminants. Possible values of the B4 attribute are:

| Range of Values | Level of Concern |
|---|---|
| 6 | Low |
| 3-5 | Medium |
| 1-2 | High |

- Attribute B5 — magnitude of contaminant concentrations (micrograms per gram wet weight) in tissues of test organisms. This attribute uses the actual level of tissue residues as an indication of the severity of concern. Possible values of the B5 attribute are:

| Range of Values | Level of Concern |
|---|---|
| < 0.1 | Low |
| 0.1-1.0 | Medium |
| > 1.0 | High |

## Data Requirements

The data used by *COBIAA* are readily available for most dredging projects and use both test and reference site data. As alluded to above, these data include: animals tested, contaminants analyzed for, toxicity data (number of animals showing toxicity), and bioaccumulation tissue residue concentrations. Default data files supplied with *COBIAA* contain any available toxicological ranking of contaminants and U.S. Food and Drug Administration (FDA) criteria (Lee and others 1991).

*COBIAA*'s data are organized into data sets. A toxicity data set is defined as an animal name, the reference toxicity, and the test toxicity. A bioaccumulation data

set is defined as an animal name, a single contaminant, the reference tissue residue level, and the test tissue residue level of that contaminant. Each project or site will consist of multiple data sets encompassing as many animals and contaminants for which data exist. These data sets are stored in a file on the computer's hard disk and may be edited at any time.

## *COBIAA*'s User Interface

The *COBIAA* user interface is an interactive environment within which the user accesses the program files, enters and edits data, and analyzes those data using rules contained within the expert system component. The *COBIAA* prototype incorporates a graphical user interface and a mouse to navigate through the program menus easily. Because the user interface will likely change significantly from this prototype version to the production version of *COBIAA*, the specifics of system design and development will not be discussed in detail. A sample data entry screen, shown in Figure 2, provides an indication of the type of user interface currently employed. A Microsoft Windows™ based program, *COBIAA* requires the minimum computer hardware needed to run Microsoft Windows™, an 80386 microcomputer with hard disk, VGA monitor, 4 megabytes of memory, and a mouse. A printer is used if available to generate printed output of the decision and logic used to arrive at a decision. The expert system portion of *COBIAA* was developed using CLIPS, an expert system shell developed by the National Aeronautics and Space Administration.

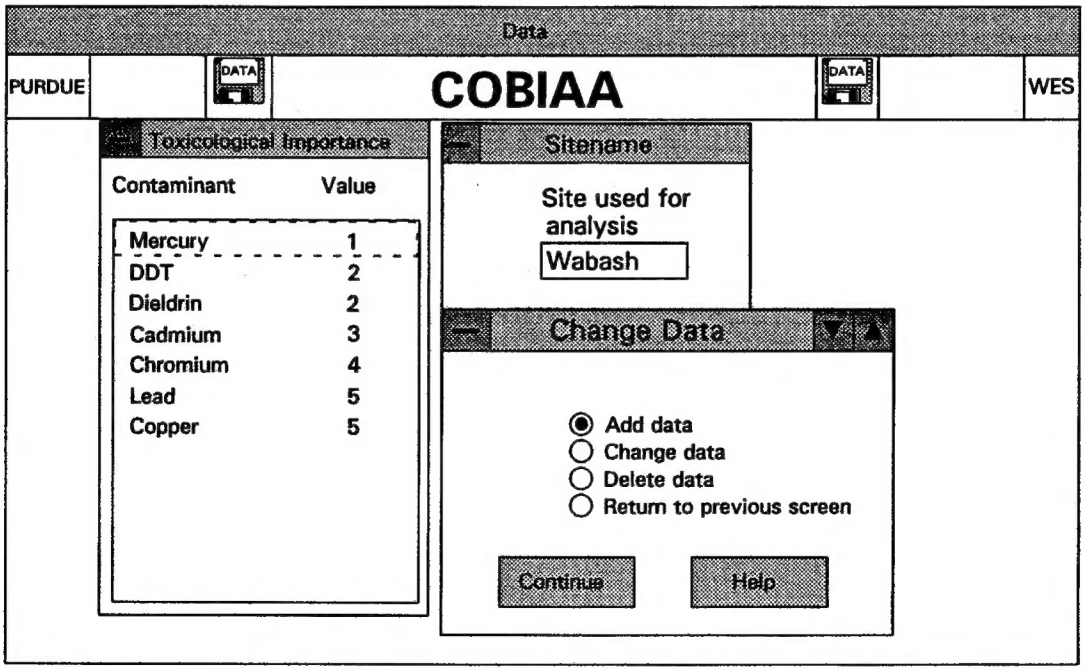


**Figure 2. Example data entry screen from *COBIAA***

## How *COBIAA* Works

*COBIAA* uses the data provided from bioaccumulation and toxicity tests to evaluate the potential for unrestricted disposal, disposal with restrictions, or whether not enough information is available requiring a regional authority decision (RAD) (Lee and others 1991). This evaluation process is accomplished by looking at the data in discrete sections, comparing them to available default values (for example, FDA criteria) and comparing the test data to the reference data. Each data set is evaluated in turn and each attribute or category is determined according to preset rules. Each attribute is assigned a value depending upon these rules. Based upon the previously defined conditions, the attributes (B1, B2, B3, B4, B5, T1, and T2) are assigned a value of low, medium, or high. The two toxicity attributes (T1 and T2) are then combined into a single toxicity attribute (tox). Similarly, attributes B3, B4, and B5 are combined to create the relative severity attribute. The toxicity, relative severity, and B1 and B2 attributes are then combined using another set of rules to reach the final decision.

The final decision reached by *COBIAA* will be one of three conclusions. If the contamination in the dredged material appears to be of little concern, then *COBIAA* will recommend disposal with no restrictions. If the material appears to be of high concern, than *COBIAA* will recommend disposal with restrictions. This option includes no disposal as well as other possible restrictions (Francingues and others 1985). The third possible conclusion is that there is not enough information available to select one of the first two conclusions and a RAD is required. This RAD may be to select conclusions 1 or 2 or may require that more information (for example, new testing) be provided and resubmitted to *COBIAA*. Dillon and Lutz (1991) provides more information concerning the types of decision categories that fall within the three conclusions presented here.

## Status of *COBIAA*

The software is currently in the prototype development stage. A working version exists, but is being constantly modified based upon feedback from the expert and several test users. The prototype is anticipated to be ready for field testing during the second quarter of FY 93.

## Conclusions

*COBIAA*, a decision support system, is being designed to provide a consistent and easy-to-use method for interpreting bioaccumulation tissue residue data as applied to dredged material disposal. Following the procedures set forth by an expert in this field will enable the user to analyze toxicity and bioaccumulation data to determine possible disposal options. *COBIAA* will provide a consistent nationwide methodology for interpreting bioaccumulation data.

## References

Dillon, T. M., and Lutz, C. H. 1991. "A Computer-assisted Expert System for Interpreting the Consequences of Bioaccumulation in Aquatic Animals (*COBIAA*)," *Environmental Effects of Dredging*, Vol D-91-4, pp 1-5.

Francingues, N. R., Palermo, M. R., Lee, C. R., and Peddicord, R. K. 1985. "Management Strategy for Disposal of Dredged Material: Contaminant Testing and Controls," Miscellaneous Paper D-85-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lee, C. R., Tatem, H. E., Brandon, D. L., Day, S. H., Peddicord, R. K., Palermo, M. R., and Francingues, N. R., Jr. 1991. "General Decisionmaking Framework for Management of Dredged Material-Example Application to Commencement Bay, Washington," Miscellaneous Paper D-91-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.